PETROLOGY OF THE HARTLEY DISTRICT. V.

EVIDENCE OF HYBRIDIZATION IN THE MOYNE FARM INTRUSION: A REVISION.

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(Plate ii; One Text-figure.)

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I. *Introduction.*

In 1931, I described a series of plutonic rocks from Hartley varying from ultra-basic to ultra-acid and showing a range of over 35% of silica. These were shown to be consanguineous and it was suggested that they represented the subsequent differentiation in place of three separate intrusions from an intratelluric reservoir—namely, gabbro, quartz-mica-diorite and granite. Later (Joplin, 1933) it was shown that instead of being normal differentiates, many of the basic types occurring in the Cox's River Intrusion were cognate hybrids which had arisen from the partial assimilation of solid hornblende-gabbro by quartz-mica-diorite magma.

In the 1931 paper the Moyne Farm Intrusion was described as a quartz-mica-diorite stock which had differentiated in place to give a slightly more basic margin and a tonalitic centre. Large blocks of diorite-gabbro and allied basic rocks were found enclosed in the diorite and a large apophysis of granite-porphyry was described as an intrusion contemporaneous with the granitic phase.

I recently re-visited the area and found that excellent exposures of the tonalite now suggest that it is an acidified diorite which has probably arisen by interaction between the quartz-mica-diorite and the invading granite-porphyry. Moyne Creek has removed some of the alluvium previously covering these outcrops, but the best exposures are to be found in material broken up by Dr. G. D. Osborne and some of his Technical College students.

Although the problem has not been entirely solved the field evidence leaves no doubt as to the hybrid origin of the tonalite, and the purpose of the present paper is to put this on record and to show that there has been a slight basification of the diorite by included blocks of gabbro involving changes similar to those described for the Cox's River Intrusion.

II. Diorite–Porphyry Reaction.

1. *Field Occurrence.*

The Moyne Farm quartz-mica-diorite stock with its included basic rocks, tonalitic centre and transgressive granite-porphyry apophysis has already been mapped (Joplin, 1931, Fig. 2). On the southern margin of the acid apophysis there are two tongues of basified porphyry, the larger being well exposed in the creek about 10 chains north-north-west of the farm-house in Por. 174, Par. of Hartley. The new exposures of tonalite occur in the creek just north of this point above the small eastern tributary stream.

The tonalite is intersected by numerous small quartz and aplite veins and by veins of basified porphyry which show sharp contacts to the invaded rock. These veins may sometimes carry small quantities of molybdenite and copper pyrites, and traces of malachite and azurite have been found. Quartz-epidote veins and segregations are fairly common and usually less sharp. Both the tonalite and the granite-porphyry contain small epidotized and partly resorbed xenoliths.

A small inclusion (1 × 2 yds.) of much epidotized diorite occurs within the granite-porphyry belt further upstream just below Cripps' orchard, Por. 175, Par. of Hartley.

2. *The Parents.*

(*a*). *Quartz-mica-diorite.*

These rocks were fully described in the 1931 paper. Certain features described there, however, are now attributed to hybridization with the included basic rocks and are mentioned below (p. 136).

For the purpose of the present paper a brief description will be repeated. The fabric is hypidiomorphic to panidiomorphic granular and usually sub-ophitic. The constituent minerals are plagioclase, hornblende, biotite, quartz and accessories which include iron ore, apatite, rutile and sphene. Epidote, sericite, kaolin and some sphene are present as alteration products.

Andesine ($Ab_{64}An_{36}$–$Ab_{55}An_{45}$) occurs in laths or elongated tabular crystals measuring from 0·75–2 mm. Hornblende and biotite form subidiomorphic crystals wrapping the felspars and thus producing a sub-ophitic fabric (Plate ii, A). Quartz occurs as small interstitial grains.

(*b*). *Granite-porphyry.*

This was described in 1931 also, so that a brief résumé only need be given here.

Under the microscope the rocks are markedly porphyritic with phenocrysts varying from 3–6 mm. in a holocrystalline groundmass with a grainsize of from 0·05–0·5 mm.

The phenocrysts consist of fairly fresh, as well as sericitized and saussuritized, tabular crystals of oligoclase ($Ab_{74}An_{26}$–$Ab_{69}An_{31}$), corroded and strained crystals of quartz and tabular flakes of much altered biotite. The biotite is usually chloritized, and sphene and epidote granules are strung out in the direction of the cleavage, but it is often completely pseudomorphed by minute grains of iron ore (Plate ii, E). Altered plagioclase phenocrysts sometimes show a fresh, slightly more acid border.

The groundmass consists of a fine mosaic of quartz and kaolinized orthoclase, small grains of magnetite and flakes of altered biotite. Occasionally a little plagioclase is present with a slightly elongated habit. Veins and patches of epidote, chlorite, haematite and carbonates bear testimony to a period of deuteric activity. Apatite is rare but may occur in comparatively large crystals.

In the original description of this rock (Joplin, 1931) it was stated that biotite occurred in tabular flakes or as altered clusters of flakes. It is now believed that the latter occurrence is due to basification of the porphyry and that the clusters represent resorbed hornblende crystals or almost completely resorbed xenoliths of diorite.

The granite-porphyry mass has been injected by aplites, quartz and quartz-epidote veins.

Rosiwal measurements have been made to determine the percentages of the various phenocrysts and of the groundmass and these are shown below (p. 133).

(*c*). *Aplites.*

Aplite veins, rarely exceeding ½ in. in width, intersect the tonalite and granite-porphyry. They are usually very fine grained and show a sharp contact with the invaded rock, but some, apparently belonging to a slightly earlier generation, are coarser in grain-size, show slight hybridization and have imparted a local monzonitic fabric to the invaded rock which was evidently hot at the time of their injection.

The aplites commonly consist of a mosaic of quartz and orthoclase and sometimes a little microperthite is present.

The occurrence of large hornblende crystals in some of the aplite veins indicates hybridization. The epidote-bearing varieties will be considered later in connection with deuteric activity.

Small quantities of metallic sulphides are often associated with the aplite veins and Dr. G. D. Osborne has observed that molybdenite sometimes occurs in thin plates on the wall of the vein.

3. *The Hybrids.*

As previously mentioned, the quartz-mica-diorite passes inwards into the tonalite, and though no actual contacts can be observed, this appears to be invaded by the granite-porphyry; thus the tonalite separates the basic diorite from the acid porphyry suggesting that it has been formed as the result of interaction between them.

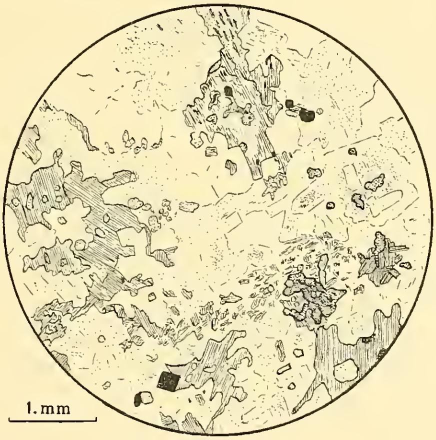
The tonalites are intersected by various hybrid veins and two large tongues of hybridized rock appear to have come from the granite-porphyry apophysis. Several types of hybrid are therefore developed, and though it is believed that the basic parent in each case is the quartz-mica-diorite or a hybridized modification of it, the identity of the acid parent is often obscure. The acid material was evidently derived from the granite-porphyry intrusion, but acidification may have been caused by the granite-porphyry magma, by a partial magma or by an aplitic magma which appears to have been the end-phase in the consolidation of the granite-porphyry magma.

In the following descriptions it is proposed to deal with the hybrids according to their structure and macroscopic appearance without regard to their parentage.

(*a*). *Tonalite (Acidified Diorite).*

The grainsize of these rocks is a little coarser than that of the quartz-mica-diorites. The fabric is very variable ranging from hypidiomorphic to allotriomorphic granular and there is often a tendency toward the sub-ophitic. All three fabrics may be recognized in different parts of a single slide (Fig. 1).

Plagioclase (Andesine, $Ab_{68}An_{32}$) may occur either in subidiomorphic tabular crystals or as large irregular grains wrapping slightly more basic laths (Fig. 1). Zoning is common, the central zones usually being much saussuritized. Quartz is not so markedly interstitial as in the quartz-mica-diorites and its consolidation appears to have been in part contemporaneous with that of the plagioclase.



Text-fig. 1. (× 12.)
Tonalite showing allotriomorphic grains of quartz and plagioclase enveloping plagioclase laths. Note mass of chlorite with inclusions of sphene and outer border of biotite at top of figure; this probably represents a resorbed core of hornblende. Note also abundant apatite.

Hornblende, though quite fresh in some rocks, is more often represented by masses of chlorite, sphene and epidote intergrown with criss-cross flakes of biotite (Fig. 1). A little epidote occurs as independent fairly well developed crystals which seem to be of primary crystallization. Apatite is particularly abundant. Orthoclase is usually subordinate but becomes more prominent in the vicinity of aplite veins where it occurs in large plates and produces a local monzonitic fabric.

(*b*). *Fine-grained Porphyritic Types.*

These rocks occur as small veins in the tonalite and in two large tongues (about 17 chs. in length), which appear to be offshoots from the main apophysis of porphyry.

In the least acidified type, orthoclase is absent and the groundmass consists of laths of plagioclase interspersed with small irregular grains of quartz and plagioclase (Plate ii, B). Hornblende occurs with biotite and there is no phenocryst development of either ferromagnesian mineral. Mineralogically this rock resembles the parent diorite, but the development of rare plagioclase phenocrysts ($Ab_{65}An_{35}$–$Ab_{63}An_{37}$) and the presence of small granules of quartz and plagioclase among the felspar laths indicate a slight hybridization.

In a more acidified type, plagioclase phenocrysts ($Ab_{69}An_{31}$–$Ab_{66}An_{34}$) measure about 2 mm. and are often zoned. Occasional lath-shaped, slightly more basic crystals of plagioclase occur as inclusions in the felspar phenocrysts (Plate ii, C). There is only a slight distinction in size between flakes of biotite developed as small phenocrysts (about 1 mm.) and those occurring in the groundmass. Biotite is now the only ferromagnesian present and is occasionally chloritized. Small grains of quartz and orthoclase occur in the groundmass and a little magnetite, apatite and sphene are present. A rock of this type has been analysed (Table 1, Anal. IV).

In handspecimen these rocks are porphyritic with small, pink, tabular felspars measuring about 2 mm. in a fine dark groundmass.

(*c*). *Basified Porphyry.*

These rocks occur sporadically throughout the main belt of the granite-porphyry.

Except for the presence of a little more biotite and of small clots, the slightly basified types closely resemble the normal granite-porphyry. Under the microscope the altered biotite phenocrysts appear to be more numerous and the clots are seen to consist of patches of criss-cross biotite measuring up to 3 mm. across. These are usually chloritized and associated with granular sphene, epidote and iron ores (Plate ii, D). Apatite is very abundant and usually occurs within the biotite-chlorite clusters which probably represent almost completely resorbed xenoliths of diorite or tonalite. Corroded quartz phenocrysts showing undulose extinction, granulation and other evidence of strain, together with tabular phenocrysts of oligoclase still occur in these slightly basified types. The oligoclase is sometimes albitized. In the groundmass a plagioclase with a somewhat elongated habit occurs with quartz and orthoclase, and in some types small flakes of biotite and chlorite are numerous.

(*d*). *Veins and Segregations.*

It is shown below that both parent and hybrid rocks have been affected by a period of deuteric activity associated with the final consolidation of the porphyry, and in some cases it is a little difficult to distinguish between veins of distinct hybrid origin and those that are the result of a later deuteric activity. In addition to the veins, small elongated patches or segregations of epidote or of rather large hornblende crystals are not uncommon, and though I have been criticized (Grout, 1937) for applying the term "segregation" to a hybrid I believe that these coarser patches are of hybrid origin, the material having been dissolved out and carried by volatiles associated with the acid magma.

The most common type of hybrid vein is one containing large crystals of hornblende at the centre and passing out into an aplite at the margin. These usually measure about ½ in. or less and intersect the tonalite.

4. *Origin of the Porphyry Phenocrysts.*

Three minerals occur as phenocrysts in the granite-porphyry and basified porphyry, namely—quartz, plagioclase and biotite. The quartz phenocrysts show corrosion, granulation, undulose extinction and every evidence of strain, and it seems fairly evident that they had crystallized prior to the injection of the granite-porphyry magma. The biotite phenocrysts also show resorption and advanced alteration into chlorite, sphene and epidote or are entirely pseudomorphed by granules of iron ore (Plate ii, E). Their appearance suggests an intratelluric origin. Although the plagioclase phenocrysts are often much sericitized or saussuritized, their margins are entire and there appears to be no evidence of either corrosion or strain. Occasionally altered felspars are surrounded by rims of fresh felspar and sometimes the occurrence of both altered and fresh felspar in the same rock suggests two generations of phenocrysts. Nevertheless, the bulk of evidence suggests selective deuteric alteration rather than two occurrences of felspar. The presence of basic cores, the absence of inverted zoning and the presence of groundmass minerals as inclusions all point to a growth *in situ*.

The origin of phenocrysts in plutonic rocks has been much discussed (Pirsson, 1899; Crosby, 1900; Watson, 1901) and various criteria have been listed to determine their intratelluric or contemporaneous origin. It seems to be agreed that the large tabular orthoclase phenocrysts of the porphyritic granites are contemporaneous and Nockolds (1932, 1933) has shown that plagioclase "phenocrysts" may grow within solid basic xenoliths enclosed in a granite magma. The "phenocrysts" of the fine-grained porphyritic hybrids have undoubtedly arisen in the way described by Nockolds and are therefore an inherent characteristic of their hybrid origin and not necessarily an inherited characteristic indicating that the porphyry was the acid parent.

In considering the hybridization processes it is important to try to ascertain the condition of the acid magma at the time of injection, and examination of the granite-porphyries and the basified porphyries certainly suggests that the quartz and biotite phenocrysts and possibly a few of the plagioclase phenocrysts are intratelluric, and may not have taken part in the subsequent hybridization of the basic rocks.

5. *Deuteric Activity.*

It was pointed out in the 1931 paper that the granite-porphyries are rather susceptible to weathering and that it was difficult to determine how much of their alteration should be attributed to deuteric activity. It was finally decided that deuteric solutions were responsible for epidotization, chloritization, some oxidation and some carbonation whilst most of the oxidation (i.e., haematite, etc.) and carbonation was due to weathering. This generalization is probably fairly correct but it seems likely that sericitization, saussuritization and kaolinization should be added to the list of deuteric processes.

The fact that all the porphyries show so much alteration invalidates any calculations that can be made in discussing the hybridization, and it will be seen below that it is impossible to reach any final conclusions regarding these processes.

6. *The Hybridization Process.*

(*a*). *Origin of the Tonalite.*

As previously indicated, the field occurrence supplies the best evidence of the hybrid origin of the tonalite, especially the coarser texture and the occurrence of ferromagnesian clots. Except for the apparent instability of hornblende, the inclusion of felspar laths in allotriomorphic grains, the sporadic zoning of felspar and the sudden transitions in fabric, the microscopic evidence is unconvincing. Nevertheless, hybridization has undoubtedly occurred, and it seems to have advanced to such a stage that little evidence of it remains.

The foregoing discussion on the origin of the phenocrysts suggests that the acid liquid responsible for these reactions consisted of potential quartz, orthoclase, plagioclase and a little biotite. Rosiwal measurements were made to ascertain the percentage weights of the phenocrysts in the granite-porphyry with the following results:

	By calculation from Rosiwal Measurement.	By calculation from Chemical Analysis.
Quartz	22·0	22·00
Plagioclase (fresh)	12·8	12·86
,, (altered)	8·6	8·62
Biotite	5·1	5·60
Groundmass	51·5	50·92
	100·0	100·00

Furthermore, slides were treated with hydrofluoric acid and sodium cobaltinitrite (Gabriel and Cox, 1929) to verify the observation that all the orthoclase was confined to the groundmass. I should like to take this opportunity of thanking Miss F. M. Quodling, B.Sc., for assistance with these staining tests. The composition of the supposed liquid fraction was then calculated on the assumption that it consisted of the groundmass plus the plagioclase phenocrysts, and an attempt was made to calculate the composition of a hybrid rock formed by interaction between this liquid and the solid quartz-mica-diorite. Though it was realized that deuteric activity invalidated any such calculation, it was quite obvious that this alone could not be responsible for the impossible results obtained by calculations based on these assumptions. The removal of 22% of silica and of the small quantity of material forming the biotite necessitated the redistribution of the other oxides and the calculated percentage of alumina was far too high to satisfy any reasonable calculation.

Another attempt was made to calculate the composition of the acid liquid by including the altered plagioclase phenocrysts among the intratelluric phenocrysts and by calculating a proportion of them as sericite. This removed a little of the alumina as phenocrysts, but the results were equally unsatisfactory.

The most reasonable results were obtained by assuming that the whole of the granite-porphyry took part in the reaction and the results of this calculation are shown in Table 1, below.

TABLE 1.

	I.	II.	III*a*.	III*b*.	IV.
SiO_2	54·37	69·78	62·06	61·67	66·65
Al_2O_3	19·64	18·99	18·25	19·30	16·89
Fe_2O_3	4·30	0·21	2·91	2·32	1·11
FeO	4·87	1·06	2·94	3·03	1·67
MgO	2·94	0·58	1·71	1·80	1·46
CaO	8·07	1·24	4·90	4·78	3·02
Na_2O	2·55	3·65	3·12	3·07	3·14
K_2O	1·01	3·42	1·61	2·17	4·54
H_2O+	0·96	0·48	1·34	0·85	0·58
H_2O-	0·11	0·13	0·16		0·13
TiO_2	1·14	0·23	0·60	0·70	0·42
P_2O_5	0·34	0·19	0·24	0·27	0·29
MnO	0·07	0·01	0·09	0·04	0·02
	100·37	99·97	99·93	100·00	99·92
Sp. Gr.	2·86	2·66	2·76		2·76

I. Quartz-mica-diorite (Basic Parent), Moyne Farm, Little Hartley. Anal. G. A. Joplin. PROC. LINN. SOC. N.S.W., 56, 1931, 53.

II. Granite-porphyry (Possible Acid Parent), Moyne Farm, Little Hartley. Anal. G. A. Joplin.

III*a*. Tonalite (Acidified Diorite), Moyne Farm, Little Hartley. Anal. G. A. Joplin. PROC. LINN. SOC. N.S.W., 56, 1931, 53.

III*b*. Theoretical Hybrid consisting of 52% of Quartz-mica-diorite (I) and 48% of Granite-porphyry (II).

IV. Fine-grained Porphyritic Hybrid occurring as vein in Tonalite, Moyne Farm, Little Hartley. Anal. G. A. Joplin.

If such be the case, then the intratelluric phenocrysts must have been dissolved and reprecipitated, and this seems possible if the basification of the liquid be assumed.

There is no doubt that the quartz-mica-diorite stock consolidated from the margin towards the centre, and structures in the tonalite indicate that it was in part solid at the time of the acid invasion. Thus the "tonalite" probably consisted of a crystal mesh of the more basic minerals and an interstitial acid liquid residuum, which represented the final residual liquid of the quartz-mica-diorite magma. If this mesh were invaded by a far more acid liquid carrying solid quartz, mingling of the two liquids would bring about the solution of the quartz, since being low in the reaction series, it would no longer be in phasal equilibrium with the new, slightly more basic liquid. The liquid would not be capable of dissolving the constituents of the crystal mesh as they are higher in the reaction series, but reaction would take place and the hornblende of the tonalite thus appears to be somewhat unstable and the felspar sometimes zoned. The hybridized liquid would finally crystallize like a normal product of differentiation and this would probably account for the normal appearance of the hybrid rock.

(*b*). *Origin of the Porphyritic Hybrids.*

Reference to the petrography of the fine-grained porphyritic hybrids indicates that the basic parent was a solid rock at the time of the acid invasion. Thus in the least acidified type the only evidence of hybridization is to be found in the presence of tiny quartz and felspar granules between the plagioclase laths and in the occasional development of plagioclase "phenocrysts" such as those described by Nockolds (1932) as forming within a solid rock immersed in a liquid. The more advanced hybrids also indicate reaction between a solid diorite or tonalite and a liquid, and show structures similar to those observed by Nockolds in xenoliths.

The quartz-mica-diorite was undoubtedly a solid when injected by the granite-porphyry, but there is no evidence of its immersion in the acid liquid. The occurrence of these types in tongues and veins suggests that the solid basic rock has been permeated or soaked by an acid liquid along certain definite channels. This raises two difficulties regarding the parentage—first, it seems unlikely that the whole of the basic rock would take part in the reaction, and second, it is difficult to envisage an acid liquid containing intratelluric phenocrysts permeating solid rocks in this way.

A graphical solution of the problem was attempted by assuming first that the whole of the granite-porphyry magma hybridized a part of the diorite. The silica-percentages of the granite-porphyry and of the hybrid were used as abscissae and the other oxides as ordinates. On producing the lines thus plotted, it was found that the curve for Na_2O intercepted the SiO_2 base line at 53·5%. This was presumably the composition of that part of the diorite that had been selectively assimilated, but material containing this amount of silica has a composition quite unlike anything that could be regarded as part of a basic rock. Potash is extraordinarily high, silica and lime fairly high and alumina extremely low. The potash could be accounted for by assuming that biotite was selectively reacted with, but this would not account for the low alumina and high lime and silica. The high lime might be due to the assimilation of basic plagioclase, but this would necessarily lower the amount of biotite and therefore the amount of potash and could not account for the other discrepancies.

The assumption was then made that the whole of the diorite took part in the reaction and another graphical attempt was made to ascertain the composition of the acid liquid. This was done by plotting the analyses of the quartz-mica-diorite and of the hybrid on a variation-diagram as described above. It was found that total iron intercepted the base line for silica at 72% and it was assumed that a liquid containing 72% of silica was responsible for the hybridization. However, when the other oxides were examined it was found that lime was too low for a normal granite or aplite and that potash and magnesia were too high. These discrepancies might be explained by assuming that there has been a selective diffusion of the magnesia from the basic parent, that lime had been removed as epidote during deuteric action and that potash had been added in the form of orthoclase during the period of aplite injection or as sericite replacing lime-soda-felspar during the deuteric period. The fact that there is scope for such speculation weakens any argument that can be put forward.

Various attempts were made to calculate the composition of a phenocryst-free liquid as was done in attempting to ascertain the percentage of the tonalite, but all results were unsatisfactory.

The assumption was then made that the hybrids had arisen by interaction between solid diorite and an aplitic magma, and the analysis of an aplite from another part of the Hartley district was used as a basis for this calculation. This rock contains nearly 77% of silica and to produce a hybrid containing about 66% required a mixture of 55% aplite and 45% diorite. Though comparable results could be obtained for silica and alumina there were great discrepancies between all other oxides, the calculated rock being far too basic with respect to these oxides. Obviously more of the acid rock required to be taken, but as this gave too high a result for silica, it is evident that the acid parent was more basic than the aplite.

Actually the most satisfactory results were obtained by using the diorite or the tonalite and the whole of the granite-porphyry as the basis of calculation. These figures were comparable with those of the actual hybrid except for alumina and potash, the former being too high and the latter too low. During the period of deuteric activity the actual hybrid rock may have suffered alkalization and potash may have been introduced as described by Browne and White (1928). Nevertheless, on this assumption it was postulated that phenocrysts suspended in an acid liquid passed into a solid basic rock, and as no mechanism for such an invasion can be explained, nor can it be assumed that the phenocrysts dissolved during hybridization, it is considered unwise to present these calculations and thus to create the impression that the results are considered to be reliable.

It is not unlikely that a part of the granite-porphyry magma selectively reacted with a part of the quartz-mica-diorite and that subsequently the whole has been modified by deuteric activity.

In the case of the basified porphyries that contain all the phenocrysts of the porphyries the presence and final resorption of diorite xenoliths in the magma can be demonstrated.

III. Diorite–Gabbro Reaction.

It was noted in the 1931 paper (p. 40) that the quartz-pyroxene-diorites and diorite-gabbros occur as inclusions in the quartz-mica-diorite in the Moyne Farm Intrusion, but at the time it was not recognized that certain features, described as characteristics of the diorite, were really characteristic only of a basified type formed by the partial assimilation of these masses.

Reaction between solid hornblende-gabbro and quartz-mica-diorite magma has been fully discussed in connection with the Cox's River Intrusion (Joplin, 1933), and as the changes are very similar, it is not proposed to give detailed petrographical descriptions or to discuss the hybridization process of the basified diorite here. Nevertheless, it seems useful to mention the main characters that can be attributed to basification and to refer to similar observations in the Cox's River Intrusion.

Thus it was noted (Joplin, 1931, p. 35) that the central zone of some of the tabular felspar crystals of the quartz-mica-diorites was crowded with small granular inclusions, and that this zone was clear as compared with a sericitized outer zone. I now believe that this clear felspar, containing granular inclusions, indicates recrystallization of the earlier basic felspar and that the slightly altered outer rim is composed of a more acid, deuterically altered plagioclase deposited during hybridization (Joplin, 1933, 1935, 1936). Furthermore, re-examination of some of the quartz-pyroxene-diorites and of the more basic quartz-mica-diorites reveals further evidence which can be attributed either to recrystallization followed by hybridization or to hybridization alone. Thus

Table 2.

	I.	II.	III*a*.	III*b*.
SiO_2	54·37	44·79	46·49	46·44
Al_2O_3	19·64	19·56	19·22	19·63
Fe_2O_3	4·30	6·01	6·68	5·75
FeO	4·87	7·79	6·02	7·34
MgO	2·94	6·16	5·89	5·67
CaO	8·07	11·81	10·88	11·25
Na_2O	2·55	1·21	2·16	1·43
K_2O	1·01	0·06	0·65	0·21
H_2O+	0·96	0·64	0·96	0·79
H_2O-	0·11	0·10	0·17	
TiO_2	1·14	1·14	0·92	1·14
P_2O_5	0·34	0·18	0·40	0·21
MnO	0·07	0·15	0·20	0·14
CO_2	—	tr.	tr.	—
	100·37	99·60	100·64	100·00
Sp. Gr.	2·861	3·055	2·967	

I. Quartz-mica-diorite. Repeated from Table 1.

II. Recrystallized Pyroxene-gabbro. Cox's River Intrusion, Little Hartley. Anal. G. A. Joplin. Proc. Linn. Soc. N.S.W., 58, 1933, 146.

III*a*. Diorite-gabbro, Moyne Farm, Little Hartley. Anal. G. A. Joplin. Ibid, 56, 1931, 53.

III*b*. Theoretical Hybrid consisting of 16% of Quartz-mica-diorite (I) and 84% of Pyroxene-gabbro (II).

plagioclase sometimes shows mottling (Joplin, 1933, p. 131) and much of the amphibole is a fibrous variety probably pseudomorphing original pyroxene.

As these basic types in the Moyne Farm Intrusion have much in common with types in the Cox's River Intrusion, it seems likely that they have had a similar origin, namely, reaction between solid gabbro and a quartz-mica-diorite magma. The blocks of diorite-gabbro on Moyne Farm would, therefore, represent slightly acidified gabbros, the quartz-pyroxene-diorites highly basified diorites and the basic types of quartz-mica-diorite slightly basified rocks. The Cox's River Intrusion is only about 1½ miles west of the Moyne Farm Intrusion, and it is reasonable to assume that the earlier gabbro intrusion had a similar composition in both places. In Table 2 it is shown that a theoretical rock consisting of 84% of the Cox's River gabbro and 16% of the Moyne Farm quartz-mica-diorite compares reasonably well with the actual analysis of the diorite-gabbro on Moyne Farm. The higher alkalis in the actual rock suggest a selective diffusion of these constituents, and the discrepancy between the iron oxides is seen to be only apparent when the figures for total iron are examined; thus in (*a*) total iron equals 13·37 and in (*b*) it is 13·90. The higher ferric iron and soda in the actual diorite-gabbro hybrid are possibly due to slight deuteric alteration.

IV. Summary.

It has been shown that the granite-porphyry magma invaded the quartz-mica-diorite whilst the latter was incompletely consolidated, its centre being a crystal mesh with an interstitial liquid. At the time of its injection the granite-porphyry consisted of a fairly acid liquid carrying solid quartz. This liquid hybridized the liquid phase of the diorite, and the solid quartz, thus no longer being in phasal equilibrium, dissolved. The liquid also reacted with the solid phase of the diorite, that is, with the crystal mesh. The resulting hybrid rock was a tonalite bearing some resemblance to a normal product of differentiation.

The granite-porphyry magma, or a partial magma related to it, also permeated the solid diorite and gave rise to fine-grained porphyritic hybrids that usually have a vein-like occurrence. As many of these veins invade the tonalite and show sharp contacts with it, it is believed that at least some part of the granite-porphyry remained liquid for some time after the complete consolidation of the tonalite and that some of these veins may be secondary hybrids formed by reaction between the acid parent and the earlier formed hybrid.

Assimilation, reaction and the long period of fluidity were made possible by volatiles, the presence of which is indicated by a period of deuteric activity.

Finally it has been shown that the diorite was partly basified by the assimilation of solid gabbro prior to the invasion of the granite-porphyry. The fact that the quartz-mica-diorite shows an earlier basification and a later acidification indicates its existence as a magma, and though it is now recognized that the Hartley plutonic complex contains many cognate hybrids, my earlier contention (1931) that there were three separate injections of magma from an intercrustal reservoir, namely—gabbro, quartz-mica-diorite and granite, is thus borne out.

V. *References.*

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EXPLANATION OF PLATE II.

(× 12.)

A.—Quartz-mica-diorite showing hornblende and biotite partly wrapping laths of plagioclase to produce a sub-ophitic fabric.

B.—Fine-grained porphyritic hybrid (slight acidification) showing plagioclase phenocrysts with saussuritized basic cores in a groundmass consisting of hornblende, biotite, laths of plagioclase and small grains of plagioclase and quartz.

C.—Fine-grained porphyritic hybrid (Table 1, Anal. IV*a*), showing plagioclase phenocrysts with included laths, flakes of biotite and small masses of chlorite, sphene and apatite in a fine mosaic of quartz and orthoclase.

D.—Basified porphyry showing large plagioclase phenocrysts and clots of biotite, sphene and apatite in a quartz-orthoclase groundmass. Note slight graphic intergrowth on right.

E.—Granite-porphyry showing corroded quartz phenocrysts with pseudo-inclusions, sericitized plagioclase phenocrysts and flakes of biotite pseudomorphed by granules of iron ore. The groundmass consists of quartz and orthoclase.